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Engineering Design File

PROJECT NO. 23833

OU 7-13/14 In Situ Grouting Project Operations, Maintenance, and Logistics

Idaho National Engineering and Environmental Laboratory

EDF No.: 5155 EDF Rev. No.: 0 Project File No.: 23833

1. Title: OU 7-13/14 In Situ Grouting Project Operations, Maintenance, and Logistics

2. Index Codes:
Building/Type WMF-700 Subsurface Disposal Area SSC ID N/A Site Area Radioactive Waste Management Complex

3. NPH Performance Category: ________ or ☒ N/A

4. EDF Safety Category: ________ or ☒ N/A SCC Safety Category: Consumer Grade or ☒ N/A

5. **Purpose:** This engineering design file describes the operations, maintenance, and logistical strategy, as well as other activities necessary to define first time, daily, and annual startup and shutdown features for the In Situ Grouting Project. This engineering design file will also describe lessons learned, assumptions, and operations for conducting sliding four 12-hour work-shifts per week.

Scope: Waste matrix contaminate grouting will be implemented in a phased approach to initiate in situ grouting operations in areas containing only low-level waste, and then advancing to the foundation grouting in the more challenging Subsurface Disposal Area areas (e.g., Rocky Flats transuranic-contaminated pits and trenches) as operational experience is gained. This phased approach will also incorporate additional drill rigs and crews as necessary to complete long-term goals.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

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1 3.	Registered Professional Engineer's Stamp (if required) N/A

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FIGURES

TABLES

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ACRONYMS

API	American Petroleum Institute
BBWI	Bechtel BWXT Idaho, LLC
COC	contaminant of concern
DD&D	deactivation, decontamination, and decommissioning
EDF	engineering design file
FY	fiscal year
GPS	global positioning system
HASP	health and safety plan
INEEL	Idaho National Engineering and Environmental Laboratory
ISG	in situ grouting
JSA	job safety analysis
MSA	management self-assessment
NEPA	National Environmental Protection Act
NIOSH	National Institute for Occupational Safety and Health
PDD	program description document
PRD	program requirements document
RadCon	radiological control
RCT	radiological control technician
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
STD	standard
TFR	technical and functional requirement
TPR	technical procedure
TSR	technical safety requirement

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OU 7-13/14 In Situ Grouting Project Operations, Maintenance, and Logistics

1. PURPOSE

This engineering design file (EDF) describes the operations, maintenance, and logistical strategy, as well as other activities necessary to define first time, daily, and annual startup and shutdown features for the Operable Unit 7-13/14 In Situ Grouting (ISG) Project (also referred to the project).

This EDF will also describe lessons learned from drilling rig accidents, assumptions, and operations for conducting sliding four 12-hour work shifts per week.

2. BACKGROUND

In situ grouting has been identified as a viable remedial action to address near-term risks posed by some contaminants in the Subsurface Disposal Area (SDA) (see Figure 1), which is located in the Radioactive Waste Management Complex (RWMC). Waste matrix contaminate grouting will be implemented in a phased approach to initiate ISG operations in areas containing only low-level waste, and then advancing to the foundation grouting in the more challenging SDA areas (e.g. pits and trenches contaminated with Rocky Flats Plant transuranic waste) as operational experience is gained. This phased approach will also incorporate additional drill rigs and crews as necessary to complete long-term goals.

The ISG grouting system is designed to minimize operational downtime. The backup system concept is integrated into the operational logistics. The first year of operations there will be one trackhoe-mounted drill rig with two high-pressure pumps and two low-pressure pumps. The project will operate the first year, Fiscal Year (FY)-05, with one crew using one trackhoe-mounted drill. The second year and succeeding years, FY-06 through FY-10, the project may operate two crews on a sliding four 12-hour shift schedule with three trackhoe-mounted drills. One high-pressure pump and one low-pressure pump will be used as backups. Other systems have backup capabilities designated. For example, drill hole locations will be identified using a Global Positioning System (GPS) mounted on the trackhoe. In the event the GPS fails, GPS backup will be provided by a project person designated as the spotter and cross-trained in surveying.

In 2001, there was an accident at RWMC during an ISG test. A subcontractor employee was struck by metal from a ruptured high-pressure fitting. When the grouting system pressure was raised, the fittings connecting the high-pressure pump to a pressure-flow sensor failed, resulting in the flying metal that struck the subcontractor employee. An investigation showed that an underrated elbow fitting was used in the grout system. The pass down of system requirements and quality oversight of the subcontractor did not prevent or detect the equipment deficiency. Investigation of this accident was documented in an accident investigation report, DOE/ID-10968, *Type B Accident Investigation Board Report, Grout Injection Operator Injury at the Cold Test Pit South, INEEL*.

In June, 2004, EDF-4897, "Evaluation and Response to the Grout Accident Investigation Report for the OU 7-13/14 Early Actions Beryllium Encapsulation Project," was issued to provide a crosswalk from the information contained in the grout accident investigation report (DOE/ID-10968) and as a response on how the Early Action Project had addressed the reported issues of providing a safe jet grouting operation. General comments were provided to address overall issues and findings, followed by tables providing response to the specific issues and findings from the report. Some of the findings and issues were beyond the scope of both projects to address and have been identified as such. The issues and responses identified in EDF-4897 will also be applied to this project.

3. SCOPE

The scope of the project includes two grouting functions: first, waste matrix contaminant grouting to mitigate further migration of selected contaminants; and second, foundation grouting to enhance waste stability to support a future cap. This EDF covers the operational, maintenance, and logistics requirements, design criteria, assumptions, lessons learned, and conclusions associated with conducting ISG at the SDA.

It should be noted that the scope of this project has changed over the past year because of several factors, such as the following:

- Acquisition Team/Subcontract Formation Group revision of the make/buy decision in June 2004 to subcontract the grout supply and injection work

- Waste Area Group 7 program refinements to the remediation strategy

- Improved inventory characterization.

The information in this EDF will be used for developing project cost estimates, safety and environmental documentation, procurement specifications, and planning for field support functions.

4. REQUIREMENTS

Requirements related to project operation, maintenance, and logistics activities are identified by two types of bases. These include technical and functional requirements (TFRs) contained in TFR-267, "Requirements for the OU 7-13/14 In Situ Grouting Project (Customer, Project, and System)."

4.1 General Requirements

The following requirements shall be met to ensure safe and effective conduct of operating, maintenance, and logistical activities:

- Grout flushing capability shall be provided, includes a self-contained waste flush system for the grout injection system

- Grout nozzle cleaning capability shall allow for frequent, user-friendly cleaning and flushing of specified grouting equipment

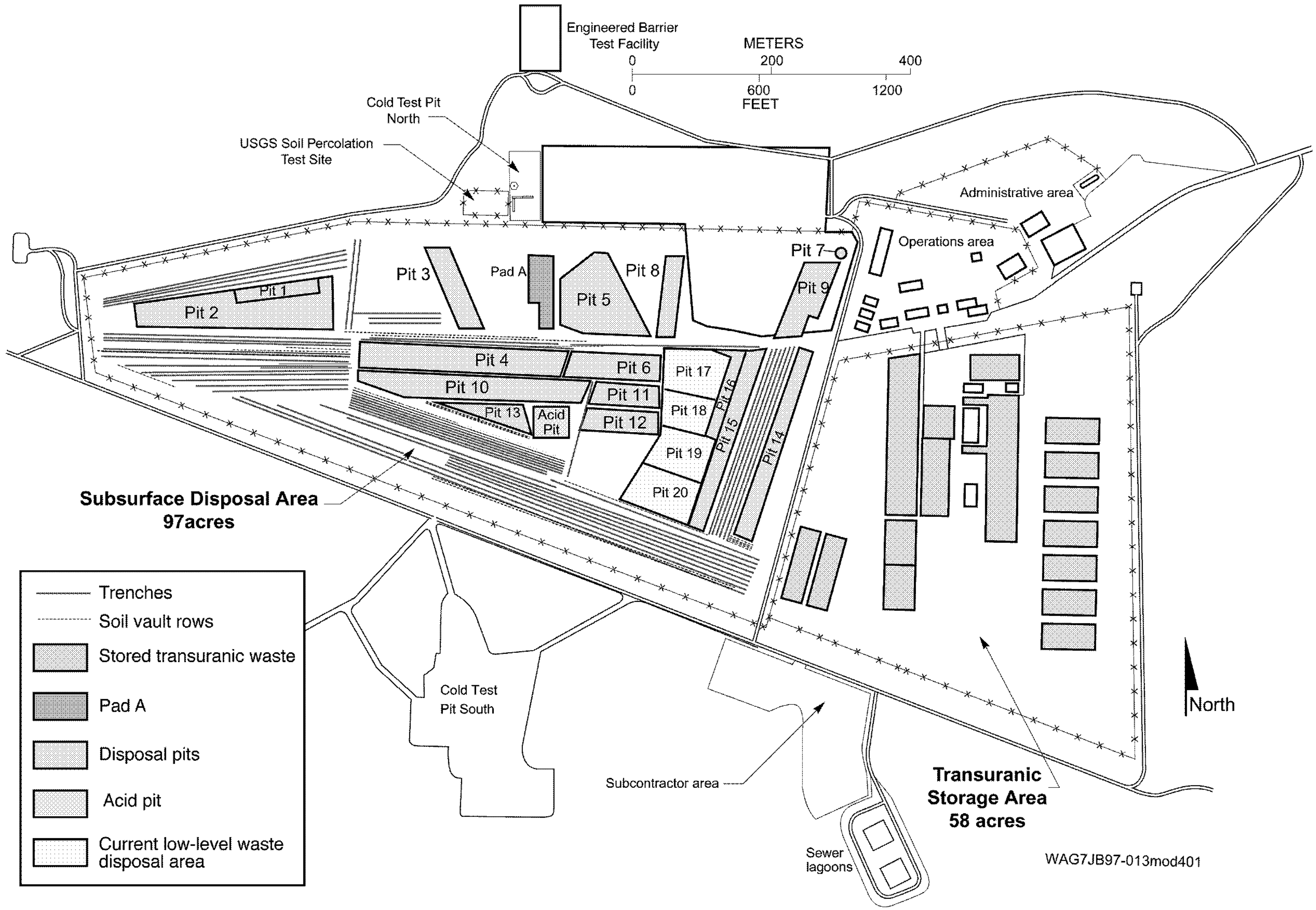


Figure 1. Map of the Radioactive Waste Management Complex, showing location of the Subsurface Disposal Area.

- High-pressure safety systems shall include the recommendations identified in EDF-4897
- Project support equipment shall be located outside the confinement and operated by workers during grouting operations
- The project shall provide personnel monitoring areas and other administrative or support areas as necessary
- The project shall be capable of reviewing the adequacy of equipment, personnel, and procedures to ensure the activities can proceed safely and in compliance with applicable requirements
- The project shall provide maintenance procedures (e.g., corrective, predictive, and preventive maintenance procedures) and establish the required frequency for maintenance activities
- The project shall conduct maintenance in accordance with Idaho National Engineering and Environmental Laboratory (INEEL) Conduct of Maintenance, as implemented in company Standard (STD)-101, "Integrated Work Control Process," or equivalent subcontractor documentation
- The project shall ensure performance of maintenance with appropriate mitigation of identified hazards and required pre-job briefings of employees as to hazards involved in their work scope, as well as hazards that may be present because of other RWMC activities
- The project shall place the project facilities in stable and known conditions for safe shutdown following completion of ISG activities
- The project shall maintain the project facilities in stable and known conditions during the layup period (after shutdown) until deactivation, decontamination, and decommissioning (DD&D)
- The project shall perform the DD&D of project facilities, systems, and components that are determined as nonessential to SDA missions
- Minimal water shall be used for cleanup after pumping is complete
- Drill string covering shall be provided to reduce personnel contamination from grout splatter (00001).

4.2 Testing Requirements

Cold (i.e., in a nonradioactive, nonhazardous environment) demonstrations of grout equipment and procedures will be necessary (TFR-267—00041).

4.3 Work Processes

Work process requirements similar to those for ISG Early Action Phase 1 will be included to allow work to be accomplished in a safe, secure, cost effective, and efficient manner.

4.4 Grout Injection

Qualified personnel will operate grouting equipment. Grout injection activities will be implemented upon approval to proceed following a formalized readiness review process.

No physical impediments will be encountered to preclude grout injection.

5. SYSTEM CLASSIFICATIONS, CATEGORIZATIONS, AND DETERMINATIONS

An ISG safety authorization basis document is being written to address the issue of system safety classification; however, the following determination will be assumed until the document is issued:

All equipment, materials, and processes are not safety class; therefore, they may be purchased as consumer grade.

The high-pressure pump, downstream piping, and pressure retaining drill string components are assumed to be consumer grade with appropriate controls to verify equipment compliance to consensus codes and standards.

6. ASSUMPTIONS

6.1 Technical Approach

The ISG technical approach baseline will be semi-remote, single-phase jet grouting within a trackhoe-mounted drill.

6.2 Technology Development

Additional technology development will not be necessary. Some technology application testing may need to be conducted.

6.3 Readiness

Plans and programs will be confirmed during the procurement award, vendor data review, and management self-assessment (MSA) processes.

Operators will have acceptable quality assurance plans, safety plans, operating procedures, and training programs.

7. DESIGN CRITERIA

7.1 Applicable Design Codes and Standards

There are no specific design codes or standards associated with operating or maintaining ISG equipment. Project requirements (see Section 4) and design requirements (see Section 7.2) associated with operating and maintaining ISG Project equipment are project-specific. Design codes and standards for the grout storage, mixing, and delivery equipment; for project support equipment and systems; and for ensuring worker safety are specified in the following project EDFs:

- EDF-5135, "OU 7-13/14 In Situ Grouting Project Grout Storage and Mixing"
- EDF-5102, "OU 7-13/14 In Situ Grouting Project Grout Delivery System"
- EDF-5153, "OU 7-13/14 In Situ Grouting Project Hydraulic Excavator and Drill-Injection Rig"
- EDF-4933, "OU 7-13/14 In Situ Grouting Project Grout Measurement and Control"
- EDF-5144, "OU 7-13/14 In Situ Grouting Project Support Facilities"
- EDF-5150, "OU 7-13/14 In Situ Grouting Project Support Systems"
- EDF-5122, "OU 7-13/14 In Situ Grouting Project Electrical Utilities"
- EDF-5162, "OU 7-13/14 In Situ Grouting Project Support Vehicles"
- EDF-5152, "OU 7-13/14 In Situ Grouting Project Environmental, Safety, and Health."

7.2 System Design Requirements

This section contains the system design requirements associated with operating and maintaining ISG Project equipment and systems. Because of the human interface considerations between ISG equipment and the operation of that equipment, system design requirements are also provided that address key ISG equipment that will be operated by subcontractor personnel and safe operation of that equipment. Equipment design and safety requirements are provided in more detail in the associated EDFs (see Section 7.1).

7.2.1 Design Documentation

The procurement specification will require the subcontractor to properly design and subsequently disclose the design of the components and equipment. The design and design verification documentation will be submitted as vendor data and will be approved before delivery.

7.2.2 Pressure System Design

The procurement specification will require the subcontractor to design the pressure system with parts compliant to the rated system pressure. The project will prepare inspection criteria and inspect the system during the receiving inspection to verify compliance.

High-pressure system components will be rated as recommended in EDF-5102.

Special wire mesh cable pulls, sleeves, and whip checks will be sized as recommended in EDF-5102.

7.2.3 Pressure System Operating Instructions

Operating instructions will be written compliant with the requirements found in Program Requirements Document (PRD)-320, "Pressure System Safety."

7.2.4 High-Pressure System Testing

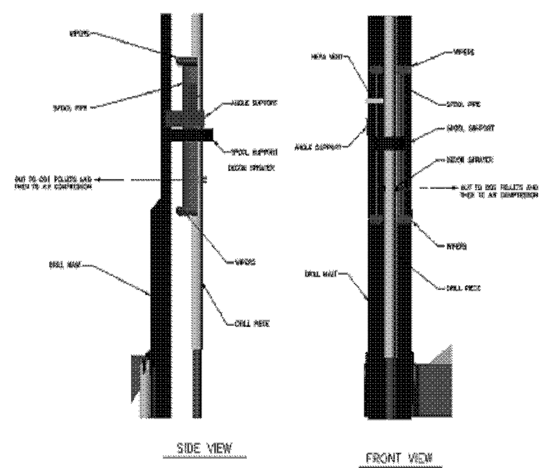
The high-pressure system will be designed to allow for both a static (i.e., leak) and dynamic test. Failure of any high-pressure system component will not be a cause for further assessment or standdown. A failed component or system will be replaced and the system retested. Leaks resulting in nonspraying drips from the system less than 50 cc per hour are not failures. Leaking connections should be tightened and the test repeated.

7.2.4.1 Static Test. At the start of each grouting season, the fully assembled system will be static leak tested to the recommended hydrostatic pressure of 15,000 psi (EDF-5102). The drill operator will blank off the rupture disk and the relief valve, attach the drill stem to the static test manifold on the cleanout truck, and then bring the system up to the designated pressure and hold for 10 minutes.

7.2.4.2 Dynamic Hydro Test. Dynamic testing will be performed as part of the system flush at the completion of grouting for each shift or after a high-pressure equipment or component changeout. The test will include, as a minimum, two water flushes. The first flush will remove any remaining grout. For the second flush—the dynamic hydro test—the drill operator will attach a new bit from the bit magazine, insert the jet bit into a metal cleanout tank, and then pressure up the system to 8000 psi with water for 60 seconds (200 gal). The drill is to be rotated and the hammer activated during the dynamic hydro-test.

7.2.5 High-Pressure Pump

The high-pressure pump must have a sufficiently low gear to produce a trickle flow of grout to prevent dirt from entering the jets. The trickle flow may also be generated by another method. Trickle flow is defined as greater than 100 cc per minute and less than 2,000 cc per minute with a positive displacement pump (verified by visual inspection).



7.2.6 Drill Mast Maintenance

The drill mast will be attached near its balance point and may be laid down horizontally to place it on the ground or on a truck for maintenance or replacement.

The drill mast will have a drill stem wiper assembly (EDF-5153 and above figure) that will clean bits before spinning on a new bit.

7.2.7 Hose and Hose Connection Management

Cement-based grouts are very viscous and highly abrasive to the system internal surfaces. The grout erodes the liner from high-pressure hoses and the drill bit nozzles. To address the abrasive nature of the grout, hoses and hose connections will be managed in accordance with the following requirements:

- Hose and hose connection management design criteria is described in EDF-5102.

Stick grease (Halliburton) will be used when assembling hoses, fitting connections, and swivel cavities to decrease grout buildup.

7.2.8 Drill Bit Changeout System

After grouting, the drill operator will remove the existing bit from the drill stem using the drill rig bottom breakout tool, drop it into a bit drop canister located on the ground, rotate the drill stem, and insert the drill stem, minus the bit, into the bit cleanout manifold in the bit change box. Water will then be circulated through the high-pressure grout pump, high-pressure hose, and drill stem to the cleanout manifold, and finally to the cleanout water tank (EDF-5102).

Before resumption of operations, the high-pressure portion of the system will be dynamically leak tested as described in Section 7.2.4.2. After the leak test, a new bit will then be remotely replaced from a bit change box or magazine of replacement bits. Personnel will not be permitted to approach the drill during this operation.

7.2.9 Grout

Grout used for this project will be cementitious as delineated in EDF-5146, "OU 7-13/14 In Situ Grouting Project Grout Selection Basis," and formulated to:

- Minimize abrasion, friction, and fluid loss
- Minimize air entrainment by including an effective anti-foaming agent
- Include a cement retarder agent in amounts sufficient to give a minimum 12-hour working time with a one-hour set time of mixing with soil
- Allow for retarder-laced water to be used in system cleanout.

7.2.10 Health and Safety Plan

A health and safety plan (HASP) will be prepared that will define the hazards and provide mitigating controls. The HASP will be updated before the MSA with the additional information provided by vendors, operating and maintenance procedures, and lessons learned from the Phase 1 grouting project.

7.2.11 Safe Operating Distance

Once grouting operations have begun, no personnel, except the operator in the trackhoe drill rig cab, will be allowed within a safe operating distance as designated by safety/radiological control (RadCon). As a safety feature to alert personnel that equipment is operating, a visible light (e.g., flashing red or yellow) will be added to the following equipment to indicate operations status:

- Trackhoe-mounted drill
- High-pressure pump
- Low-pressure pump.

7.2.12 Operating Procedures

Technical procedures (TPRs), job safety analyses (JSAs), and radiation work documentation will be prepared before operation.

7.2.13 Training Procedures

Training qualifications will be prepared and training conducted before operations activities.

7.2.14 Management Self-Assessment Guidelines

An MSA plan will be drafted and approved, and a checklist developed by RWMC and ISG contractor personnel.

7.2.15 Equipment Vendor Data

Vendor data provided by the ISG equipment vendor will include, but not be limited to, the following vendor data:

- An operations and maintenance manual that describes equipment operations
- A training program for personnel operating and maintaining the equipment.

7.2.16 Grout Injection System

The grout injection system (see Figure 3) will include the following:

- Trackhoe-mounted drill with drill mast
- High-pressure pump
- Low-pressure pump with delivery hopper.

The trackhoe-mounted drill (see Figure 3) will be specifically designed as recommended in EDF-5153.

Support equipment for the grout injection system will be as recommended in EDF-5162.

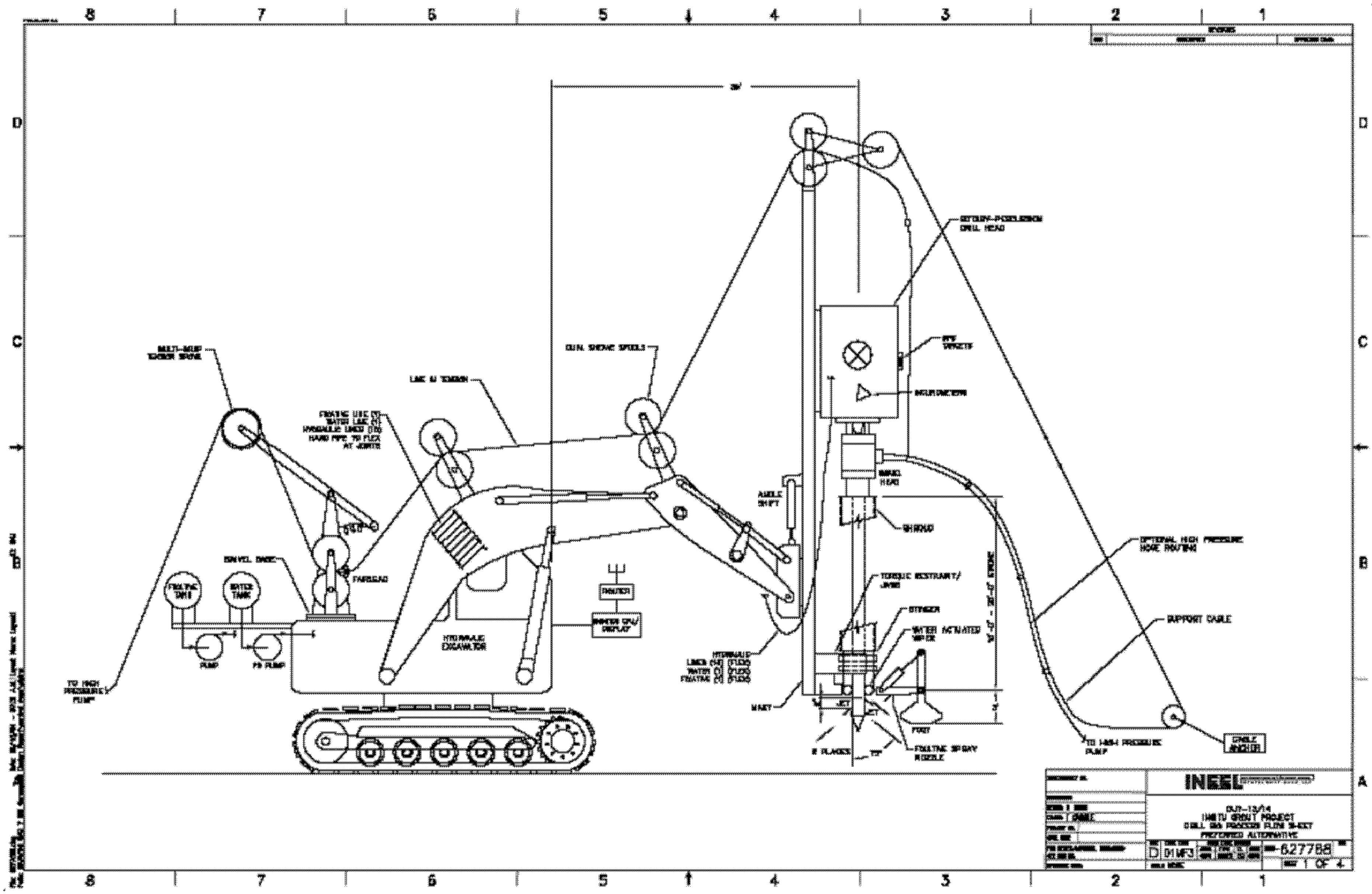


Figure 2. Typical grout injection system.

7.2.17 Grout Storage and Mixing System

Grout storage and mixing equipment and processes are described in EDF-5135 (see Figure 4).

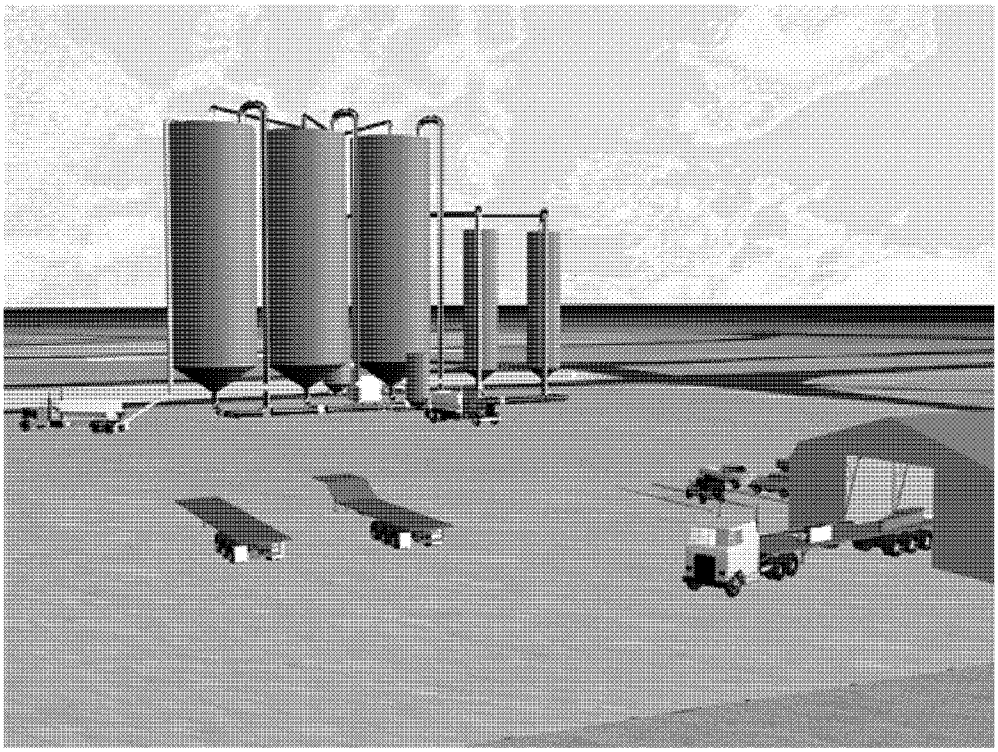


Figure 3. Artist's rendering of typical batch plant.

7.2.18 Major Equipment Backup

For the first year, one complete operating equipment set (trackhoe-mounted drill, high- and low-pressure pump, and mast) will be required with one additional high-pressure pump and mast serving as backup.

For the second year and succeeding years to 2010, two or more operating equipment sets (trackhoe-mounted drill, high- and low-pressure pumps, and mast) will be required, with one complete equipment set serving as backup.

7.2.19 Specific System Backup

Backup systems for specific equipment will be identified to minimize operational downtime. For example, the trackhoe-mounted drill will have a GPS system mounted to identify drill hole location. Subcontractor personnel designated as the positioning and grout estimator will also be cross-trained in surveying in case the GPS fails.

8. RISKS

Because of the human interface considerations that need to be addressed in the design of ISG equipment and systems, risks associated with operating and maintaining ISG equipment and systems are contained in the EDFs that address ISG equipment and system design (see Section 7.1 for a list of applicable project EDFs).

9. LOGISTICS SUPPORT

This section summarizes the recommended approach for conducting ISG and equipment maintenance at the SDA. This information was originally developed at a stage in the project when it was planned that company personnel would perform grouting operations and equipment maintenance tasks. The information in this EDF will be used for developing project cost estimates, safety and environmental documentation, procurement specifications, and planning for field support functions. These activities also identify the personnel, equipment, and materials necessary to accomplish the project. The information may also be used as needed by the subcontractor to plan ISG operations.

9.1 Operations Personnel

RWMC operations personnel will perform ISG operations and equipment cleanout activities as follows:

- First year, FY-2005, with one trackhoe-mounted drill
- FY-2006 through FY-2010, with two or more trackhoe-mounted drills
- Duration of normal operation will be from March to November each year.

9.2 First Year Sequence

The first year sequence (FY-2005) will include operator training, certification, conduct of an MSA, and then actual operations inside the SDA. A cold demonstration of the equipment will be performed at Cold Test Pit North. Training, certification, and annual startup and winterization procedures will be written before startup.

9.3 Batch Plant Operations

Batch plant operations will be conducted in an Idaho Falls area facility for FY-2005. Out-year placement of the batch plant will probably be located on the south side of the SDA.

9.4 Backup Equipment

Using replaceable drill stems on the mast and having one complete mast set with one high-pressure pump and one low-pressure pump will greatly enhance production by limiting downtime. Specific details are provided in the operations and daily cleanout sections.

9.5 Drilling Pattern

Drilling hole spacing should be 17.32-in. apart to obtain a 20-in. triangular pitch (see Figure 5 for a typical layout).

9.6 Operator Training

Operators will be trained on and responsible to perform pump maintenance to facilitate early detection of problems and acceptance of personal responsibility for equipment readiness (PRD-320).

The RWMC training group will prepare a training plan (see Appendix C, Table 2). Training documentation will be as follows:

- RWMC facility operations is responsible to develop training, operating, and maintenance procedures that are compliant with Manual 12, *Training and Qualification*, Program Description Document (PDD)-1045, "RWMC Training Program Description," and PRD-320.
- Training will be accomplished over an eight-week period, beginning with classroom covering the basis for equipment operations. Additional training will cover fast cruise operations and conduct of the MSA. After successful conduct of the fast cruise, on-the-job training will be conducted to increase worker proficiency.

Before project personnel initiate grouting mobilization activities, they will all receive project-specific training as identified the training plan (see Appendix C, Table 2). Training requirements will be based on worker job tasks and the location of this work (i.e., required zone access).

9.7 Containment

A 10- to 12-in. layer of clean overburden will be removed from the area to be grouted before grouting to provide a containment for grout returns. The soil will be replaced over the grouted area as soon as practical or within two weeks after grouting.

9.8 Grout Returns

For cementacious grout, grout returns at the surface are anticipated to be about 1 to 2 gal per hole in the pits and trenches, but can be 5 to 10 gal per hole in undisturbed soil.

Grout returns may be measured electronically (see EDF-4933, Appendix F, Video Recording of Grout Returns). As a backup, personnel will be trained in estimating returns. This training will be similar to the operations training for estimating drum volumes.

Based on lessons learned from recent operational experience, the following recommendations should be adopted to reduce grout returns:

1. The high-pressure pump must have a sufficiently low gear to produce a trickle flow of grout to prevent dirt from entering the jets. Trickle flow is defined as greater than 100 cc per minute and less than 2,000 cc per minute.
2. A tapered auger flight bit, combined with rotating the drill stem as the bit descends to the top of the waste seam.
3. The subcontractor drill operator must be given the latitude to change several parameters (e.g., stem rotation, pressure, and step size) while injecting grout.

9.9 Fixative Material

Once the grout has set, a bright colored fixative material (e.g., latex paint or wax) will be sprayed on top of the grout within six hours before grout hardening to fix potential contamination.

9.10 Pump Switchout

Switching to the replacement pump should require no more than 15 minutes.

9.11 High-Pressure and Low-Pressure System Service and Maintenance

Time duration for servicing and maintenance of the high- and low-pressure systems will be determined by observing wear patterns over each period of time.

10. RESULTS, CONCLUSIONS, AND DETERMINATIONS

Subcontractor operations personnel will perform normal and off-normal equipment operations and clear plugged nozzles.

Subcontractor maintenance personnel will perform equipment repair, preventive maintenance, and other job-site maintenance activities, including replacing hoses and fittings.

REVISIONS		
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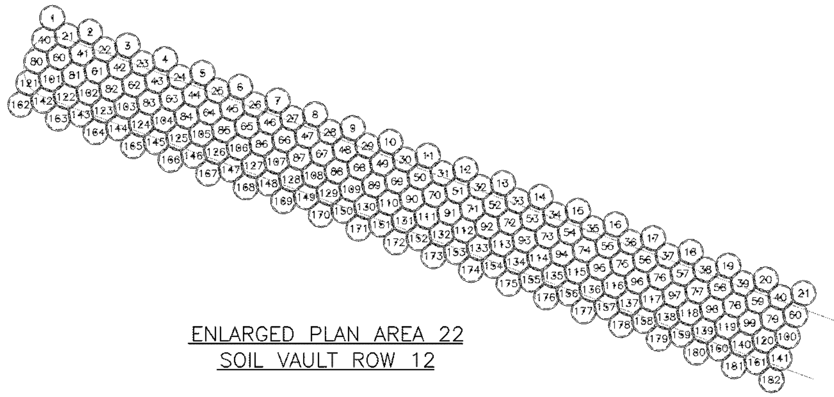

ENLARGED PLAN AREA 22
SOIL VAULT ROW 12

COORDINATE TABLE

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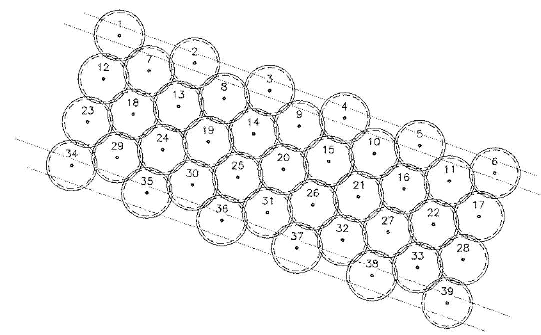

ENLARGED PLAN AREA 15
SOIL VAULT ROW 14

NOTES

1. SOIL VAULT ROW 12 AND SOIL VAULT ROW 14 ARE AT THE TOP OF THE LIST IN THE SEQUENCE TABLE SHOWN ON FIGURE 1. THESE FIRGURES SHOW THE CONFIGURATION OF THE HOLES TO BE DRILLED AND INJECTED WITH GROUT.
2. THE NORTHING AND EASTING DATA IN THE CORDINATE TABLES ARE YET TO BE DETERMINED BECAUSE THE ACTUAL POSITIONS OF THESE SOIL VAULT ROWS IN THESE RESPECTIVE AREAS IS YET TO BE PRECISELY DEFINED.
3. WHEN THE POSITIONS ARE DEFINED, THE NORTHINGS AND EASTING COORDINATE DATA WILL BE PROVIDED TO THE SUBCONTRACTOR FOR ALL THE SOIL VAULT ROWS AND TRENCHES IN THE SEQUENCE TABLE.

FOR DRAWING INDEX SEE DRAWING NO.
SUBCONTRACT NO.
INEEL
REQUESTER: FRANK WEBBER
DESIGN: P. BUNNELL
DRAWN: R. PENCE
PROJECT NO. 23833
SPCL CODE
NO SCALE
OU 7-13/14 ISG PHASE 2
ENLARGED PLANS
AREA 22 SVR-12 AND AREA 15 SVR-14
FOR REVIEW/APPROVAL SIGNATURES
SEE DAR NO.
EFFECTIVE DATE:
DESIGN PHASE: CONCEPTUAL
SAFETY CATEGORY: CG
SIZE D — CAGE CODE 01MF3 — INDEX CODE NUMBER: AREA 098, TYPE 0100, CE 01, ORIG 090 — DWG- — REV
SCALE: NONE
SHEET FIG-3

Figure 4. Typical hole layout.

10.1 Operations Parameters

This section summarizes the recommended approach for conducting ISG operations and equipment maintenance at the SDA. This information was originally developed at a stage in the project when it was planned that company personnel would perform grouting operations and equipment maintenance tasks. The information in this EDF will be used for developing project cost estimates, safety and environmental documentation, procurement specifications, and planning for field support functions.. The information may also be used as needed by the subcontractor to plan ISG operations.

For the first year, FY-2005, one crew will operate one trackhoe-mounted drill rig. For the second and succeeding years, FY-2006 through FY-2010, two crews will operate two or more trackhoe-mounted drill rigs on sliding four 12-hour shifts (see Table 1).

Table 1. Projected crew requirements for conducting in situ grouting at the Subsurface Disposal Area.

Crew Members	FY-2005 Operating Plan	FY-2006 through FY-2010 Operating Plan
Operator—heavy equipment operator	2	4
Job supervisor and site safety officer	1	2
Roving field team leader (job supervisor relief)	0.25	0.5
High- and low-pressure pump operators	3	6
Spotter	1	2
Radiological Control technician (RCT)	2	4
Facility RCT (relief)	0.25	0.5
Laborers	1	2
Total crew	10.5	21
Times crews per drill rig	10.5	63

10.1.1 Project Startup

Project startup activities will support conducting the fast cruise (i.e. shakedown grouting operations to demonstrate procedures and operational competence at an area within the SDA Cold Test Pit or at the subcontractor's facility) in conjunction with performing the MSA. Following setup and testing, the fast cruise will consist of placing at least four test grout columns. Additional columns may be placed to establish an experience base.

10.1.2 Grout Sequence and Contaminates of Concern

Buried waste inventory information will become available to the project from the buried waste inventory analysis activity being conducted in FY-2004. Contaminates of concern (COC) for the FY-2005 campaign are anticipated to be Tc-99 and I-129. Subsequent COCs may include uranium. Future campaigns may include foundation grouting.

A typical grout layout is described in Section 9.5 and illustrated in Figure 5

10.1.3 Documentation

10.1.3.1 Startup. Documentation necessary for startup will be prepared before commencing work activities. Project documentation recommended for startup is identified in Appendix C.

10.1.3.2 Operations and Maintenance Documentation. The following types of operating and maintenance documentation, and subcontractor equivalents, will be prepared before commencing work activities in the SDA:

- TPRs for normal operating and abnormal conditions
- JSAs and operations related tasks
- Corrective maintenance work orders
- Preventive maintenance work orders
- Radiological work permits
- Safe work permits
- Lockout/tagouts specific to the equipment
- Winterization and dewinterization plan
- Calibration plan
- Spare parts equipment list.

10.1.4 Site and Area Preparation

A demonstration test area (i.e., Cold Test Pit North) will be prepared to set up, and the equipment tested before mobilizing to the RWMC SDA area. Equipment startup and operations procedures will be developed. Training will be conducted before mobilization at the Cold Test Pit site.

About 10 in. of soil will be removed from the area to be grouted (nominally 10 ft^2) to confine the returns.

A laydown area outside of the SDA will be established for the placement of equipment and materials (e.g., cleanout water, unused grout, drill bits, drill stems, assemblies, and nozzles) until the grouting is completed.

10.1.5 Mobilization of Batch Plant and Grout Injection Equipment

Batch plant erection and testing may occur at the same time as the mobilization of the grout injection equipment.

Mobilization of grout injection equipment will occur on two separate occasions: first, at the Cold Test Pit North for demonstration activities, and second, inside the SDA for field operations.

Mobilization of equipment will consist of moving the drill rig, control trailer, RadCon trailer, other support vehicles, and drilling support materials to the project site. The only intrusive tasks that will occur during site preparation and mobilization will be to establish zones and designated work areas using posts.

Site boundaries or "zones" will be established to ensure that project and non-project personnel are aware of restricted and potential hazard areas. Access and egress from the specific project site entry zone (EZ) will be through the RadCon trailer at specified entry control points.

The RadCon trailer will be located next to the task site area. The RWMC RadCon office (WMF-601) may serve as an alternate location. The RadCon trailer will serve as a radiological survey station when entering or exiting the project work area, and as an instrument storage and calibration area. The RadCon trailer will also include mobile communication equipment, such as hand-held radios and a mobile phone.

The office support trailer will be equipped with other administrative support equipment for integrated grouting activities.

Monitoring equipment will be staged and setup. A video monitoring system will be staged and tested.

An emergency response station will be staged near the project work area exit. This station will include:

- Eyewash station (temperature controlled)
- Fire extinguishers (inspected)
- First-aid kit (inspected)
- Spill kit.

Personnel safety zones, barriers, and postings will be established and an equipment safety walkdown will be conducted before startup.

High wind speed and contamination levels may require downtime for drill rig operations. Engineered controls (e.g., water or a fixative sprayed on the surface, or mats and strategic placement of personnel) may be used to mitigate fugitive dust issues.

10.1.6 Setup, Test, and Demonstration

Major equipment items will be staged, connected, inspected, and tested. Equipment interfaces will be verified as part of testing. System checkout will follow approved and controlled procedures and processes.

The grouting rig, support equipment, and materials will be staged in designated areas. After equipment staging, the system will be checked to ensure proper operation before grouting. Checks include the following:

- Inspection of high-pressure components
- Leak and hydro testing if pressure system components have been changed since last use
- Calibration check of grout flow meters
- Check of measuring and data collection equipment
- Setting of grouting parameters (i.e., step distance, step rate, and drill stem rotation)
- Flushing of pumps and drill system to remove residual materials.

10.1.7 Hydrostatic and Leak Test Methods

Hydrostatic and leak tests will be conducted in accordance with Section 7.2.4 of this EDF.

10.1.8 Management Safety Assessment

RWMC and ISG contractor personnel will draft and approve an MSA plan and develop a checklist.

10.1.9 Operational Activities

The activities described in this section will be performed for both the demonstration and actual operations of ISG in the SDA.

Before beginning startup of daily ISG operations, pre-operational activities will be completed, which include as a minimum:

1. Perform daily plan of the day
2. Conduct site readiness inspection
3. Conduct daily equipment safety and readiness inspections
4. Conduct daily radiation survey and review the radiation work permit
5. Conduct pre-operations check of equipment and systems
6. Verify that the batch plant is in operation
7. Verify that the area has been roped off with appropriate signs and barriers.

Once the daily pre-operational activities are completed, the ISG delivery system is placed in the ready position over the starting point on a pit or trench by using the equipment-mounted GPS system. Grout is delivered to the external grout hopper and the low-pressure grout delivery pump is engaged allowing a recirculation of the grout in the hopper. Grout will also be flowing to the high-pressure pump inlet and out through the nozzles (trickle flow through the nozzles is established). Once it is verified by remote camera that the water in the high-pressure lines has been replaced by grout (visual observation of the trickle flow), the grouting operation is considered to be in the ready condition.

Drilling takes place at a predetermined rotational rate as the drill stem is driven through the waste to the basalt by rotopercussion action (trickle flow through the nozzles is maintained). Once the drill stem reaches the basalt or refusal, the high-pressure pump is engaged and the grout delivery pressure is brought up the predetermined pressure. When the system reaches the predetermined pressure, the rotating drill stem is withdrawn in precise, predetermined increments until the nozzles reach a predetermined position at the top of the waste, but at least 3 ft below the top grade. At this point, the high pressure is reduced to a low-pressure trickle flow. The drill stem is fully withdrawn, and the trackhoe drill operator realigns the drill stem to a new predetermined position on a 20-in. triangular matrix.

Note: Based on lessons learned from recent operational experience, refusal will be determined by the subcontractor drill operators knowledge of the position of the drill tip in relation to the start of drilling through the hard pan to a tip position between the top of the waste seam and the basalt formation.

If refusal occurs during the down drilling within 3 to 4 ft from the surface, the drill stem will be retracted and the system will be moved to one of four different locations on the compass 6 in. from the original hole. If any one of these positions allows a greater than 4-ft insertion of the drill stem, then grouting will be performed.

At the completion of the injection, high-pressure pumping is reduced to a low-pressure trickle flow. The operator will relocate the rig over next hole and repeat the sequence. If grouting operations are delayed for more than 20 minutes, the operator will spray fixative material on the drill tip to fix any potential contamination.

To maintain ISG equipment operability during ISG operations, the following operational considerations will be followed:

- It is important in grouting operations to maintain a continuous trickle flow in the nozzles when moving between holes to avoid plugging when not jet grouting

- If a "foot" is installed on the bottom of the mast, the foot must be cleaned or covered before moving out of a containment area.

Column diameter should be verified periodically, perhaps every 50 to 100 columns. The measurement device will be a disposable mechanical tool positioned by a separate crane or boom. The device will be a direct reading tube on a shaft system that can be read from a distance. These mechanical tools can be brought back to the surface.

10.1.10 Normal Shutdown

Following the shutdown of the ISG delivery system, the top surface of the recently grouted region will be sprayed with the fixative material to fix surface contamination within six hours.

A drill string wiper assembly will be installed so that the drill stem can be coated to prevent formation of potentially contaminated grout dust on the drill stem above the assembly (see Section 7.2.9). The washout water truck has a disposable tank and a metal tank on the back of a truck. Cleanout water will have a small amount of retarder added to reduce grout drying in the systems.

The washout water truck is moved near the grout injection system. With the jet bit inserted 3 to 4 ft in the ground, the trackhoe drill operator flushes the liquid grout into the tank with low-pressure air. The operator mechanically removes the bit and drops it in the mud, and hot wax is sprayed on the drill stem threads. The operator then places the drill in position, the drill stem is extended into the tank, and a high-volume flush is performed for 30 seconds. The drill stem is then extracted and a new jet bit attached.

The operator will then place the drill stem with jet bit into a metal dynamic test tank and pressure up the system to the recommended operating pressure with water for 60 seconds for the dynamic pressure test cycle. The drill is to be rotated and the hammer activated during the dynamic hydro test.

After cleanout, the system is ready for movement to a new position. The ISG delivery system is positioned using the GPS, while the ancillary high-pressure pumps, hopper, and low-pressure pumps are moved along with the system.

These actions leave the system in the ready mode for the next day's grouting campaign. All open-top grouting equipment, such as the vibrating screen and grout hopper, is covered to avoid debris in the pumping equipment.

10.1.11 Abnormal Operations

If work stoppage occurs because of abnormal conditions (i.e., interface failures), grouting operations will be suspended until interfaces can be restored. The primary impact will be unplanned costs because of downtime and interface recovery activity. Suspended operations will require equipment to be placed in a temporary standby mode (including system cleanout) and then restarted per normal procedures. It is anticipated that most interface failures will be recovered within a few days, if not hours. Abnormal conditions include, but are not limited to, those conditions described in the following subsections.

10.1.11.1 Plugged Injection Nozzles. The initial symptom of a plugged injection nozzle is a spike in grout pressure. Causes of injection nozzle plugging include, but are not limited to, solidified grout particles and rubber particles from the hose. Initially, rotopercussion will be used to clear a plugged nozzle. If that fails, a new jet bit will be attached.

10.1.11.2 Failures or Leaks in Pumping Equipment. If a high-pressure pump component fails to the point that the designated pressure cannot be achieved, the system will be disconnected and moved out of the area for cleanout and repair. The backup system will be moved into position and connected. Troubleshooting will be performed and the high-pressure pump will be repaired using the inventory of spare parts. Maintenance personnel will perform equipment failure repairs. Grout leaks greater than 50 cc/min. occurring on components of the injection system will require maintenance or changeout.

10.1.11.3 Leaks in System Swivels or Connectors. System leaks that cannot be expeditiously stopped will be dealt with by replacing the mast with the backup mast and hoses as necessary. The mast to be repaired will be sprayed with a fixative material to fix potential contamination and then repaired using the inventory of spare parts or taken to the repair facility.

10.1.11.4 Stuck Drill String. The cleanout truck will have a selection of drill stems available for changeout.

The subcontractor will be required to submit a stuck drill string recovery procedure as vendor data; however, the following process is anticipated.

The drill stem will be torqued and pulled by a force not to exceed the minimum yield strength of the drill stem. (The drill rig pulling capability may be less than the drill stem strength.) The formula to be used for combined torsion and tension on drill stem is detailed in American Petroleum Institute (API) recommended practice (RP) 7G, *Recommended Practice for Drill Stem Design and Operating Limits*, paragraph 12.3 and Appendix A.9, formula A.16.

If the pipe cannot be removed, an attempt will be made to drive the steel to the bottom. Then the upper portion of the drill stem will be removed using the rotational hydraulics of the drill, and the stuck piece will be abandoned in place. Following removal, a new section of steel will be added and the grouting process will be continued.

10.1.12 Emergency Operations

Possible emergencies that could occur during ISG operations include, but are not limited to, fire, explosion, or a sudden high radiation field.

10.1.12.1 Fire. In the event of a fire inside the ISG delivery system, the system will be shut down using the emergency shutdown switch. The emergency shutdown switch, which will be located inside the drill rig and close to the high-pressure pump, will shutdown high-pressure operations. A pulse of water may be valved into the system from a water supply designated specifically for extinguishing a fire to make sure the grout does not cure inside the components.

10.1.12.2 Explosion Below Grade. If an explosion below grade occurs, the system will be shut down using the emergency shutdown switch. After the source of the explosion is determined, RadCon and/or safety specialists will survey the area and recommend suitable precautions to be taken prior cleaning the system with emergency water flush before total shutdown for the ensuing investigation.

10.1.12.3 High Radiation Field. If the operating limit for radiation dose is exceeded, as determined by the RadCon or safety specialist, the system will be shut down using the emergency shutdown switch. After the source of the high alarm is determined (anticipated to be in a grout return), RadCon specialists will survey the area and recommend a suitable shielding to be applied before resumption of operations.

10.1.12.4 Overpressure Condition. If the system becomes stuck in an overpressure condition, probably because of plugging of nozzles or other components in the system, the following automated system responses will occur:

1. An automatic pump-clutch tripout will be activated in the event of an over-pressurization above the safety trip value.

2. If the automatic clutch tripout fails, the relief valve would open.

3. If the relief valve fails, the rupture disk would burst.

In the unlikely event that all three automated actions fail, the operator will manually shutdown the system.

In the unlikely event that the system is stuck at a pressure that is lower than the rupture disk pressure, a remotely operated bleed valve will be operated to reduce the system pressure. A bleed bolt is also provided.

If the system encounters a fitting or hose rupture, the fitting or hose will be replaced as quickly as possible and the system will be restarted. Then the cause of the failure will be investigated.

10.2 Batch Plant Data

Viscosity and density data for each grout batch will be entered in a logbook or datasheets at the batch plant.

10.3 Data Collection

The following data will be entered in a logbook, on data-sheets, or electronically generated by a data logger see (EDF-4933 for additional details for measurement data):

- Description of work completed, including column identification numbers (provided by the contractor) and a sketch identifying which columns were completed
- GPS coordinates for the columns emplaced
- Grout column geometry (i.e., column diameter, length, and location number) per column
- Beginning and completion time for each column
- Number of nozzles, including orifice size
- Flow rate and measured grout volume for each column
- Average pump pressure per column or pressure profile during problems such as a plugged jet

- Dwell time on a step per column or vertical lift speed
- Vertical step size in inches or speed continuous vertical lift per column
- Rotational speed per column
- Drilling record (i.e., total depth, drilling duration in seconds, and total jetted height) for each column
- Inclination and direction of drill rod
- Estimated volume of grout return and changes in viscosity per column
- Lessons learned
- Other pertinent observations per column, including off-normal occurrences such as ground heave, nozzle plugging, or drill stem refusal.

Data from the data loggers will be transmitted to a field computer as they are being generated. Data generated from logbook entries or datasheets will be entered in a field computer on the next day.

10.4 Maintenance

10.4.1 Reliability, Availability, and Operability

Gaining the highest system reliability is based on an aggressive preventative maintenance schedule, maintenance on backup equipment, staging of backup equipment, and stocking adequate quantities of spare parts. The technical baseline that drives the maintenance schedule is documented on contractor Form 433.35, "Preventive Maintenance (PM) Justification," or a subcontractor equivalent. The reliability of the overall grouting system would be rated by the percentage of operational time (no unplanned downtime).

The most conservative factors would be to determine the manufacturer's allowable range of maintenance schedule and any unscheduled maintenance needed during process operation would be considered an "off-normal occurrence." The design maintenance philosophy is based on scheduling and performing preventative maintenance before any component being able to fail. High-pressure grout supply hoses and the drill swivel will be replaced on a schedule that will be developed based on the manufacturers recommendations, inspections, and operational experience. Critical equipment will have redundant backups installed, if possible; otherwise a complete backup system will be staged and ready at the job site. Spare parts will be stocked and reordered when a predefined minimum quantity is reached, which is based on maintaining a sufficient number of spare parts.

Grouting operation work process flow charts will be developed to reduce operational inhibitors caused by restrictive interfaces. Independent and redundant utility interfaces between the RWMC utility systems and the ISG Project systems will be maintained. Scheduled preventative maintenance will be performed on all ISG Project systems.

10.4.2 Inspectability and Maintenance Testing

The primary wear item in the system is the high-pressure hose. The hose will typically fail by abrasive damage to the lining. This will result in strips of lining plugging the jets and/or grout penetrating the lining and forming a bulge under the cover. Hammer unions have a greater factor of safety than hoses and rarely fail even in extreme service. However, if the hose-end fittings are improperly installed or fatigued, the fitting can come off the hose.

10.4.3 High-Pressure Pump Maintenance

The high-pressure pumps are subject to high wear and high maintenance needs. The following system configuration will minimize wear and facilitate maintenance:

- The high-pressure pumps will have fluid ends sized optimally for the required flow and pressure
- The pumps may be mounted on a truck, trailer, or skid so that they can be quickly replaced and removed from the area and serviced as needed. (A truck-mounted unit can provide an environmentally controlled place for the operator.)

10.4.4 Swivel, Hose, and Hose Connection Maintenance

The high-pressure swivel is also a high wear item, but failure occurs by leakage past the seals and is not considered to be a major hazard. Swivel durability is expected to be similar to the high-pressure hose. Suction and discharge hose connections are subject to high wear and high maintenance needs. High-pressure hoses and swivel will be replaced if inspections show replacement is necessary (see EDF-5102 for additional details).

10.4.5 Low-Pressure Pump Maintenance

The low-pressure pumps may or may not be mounted on a truck, trailer, or skid so that they can be quickly replaced and removed from the area and serviced as needed.

10.5 Spare Parts

To facilitate repairs and maintain operational efficiencies (as discussed in other sections of this EDF) the following spare parts are anticipated for FY-2005:

- High-pressure pump to replace truck-, trailer-, or skid-mounted high-pump
- Low-pressure pump to replace truck-, trailer-, or skid-mounted low-pressure pump
- Two complete sets of hoses both suction and discharge
- 2 complete sets of hose connections.
- 2 swivels.

Spare part requirements for subsequent years will be based on the aforementioned list, multiplied by the number of operating drill rigs (three or more), and factoring in operational experience obtained during the first year's operations.

10.6 Reducing the Amount Water used for Cleanout and Handling Cleanout Water and Unused Grout

A typical batch plant, ready-mix truck, and injection system cleanout would generate about 13,500 gal of cleanout water per week (see Appendix B for more detail). The alternatives described below would reduce this to about 3,500 gal of cleanout water per week.

10.6.1 Ready-Mix Truck Cleanout

Standard ready-mix trucks have 200-gal wash water tanks. This water should be premixed with a liquid cement retarder. The tank would be refilled while receiving the grout. After each load of grout is delivered, the driver will use 100 gal of retarder laced washup water to clean the drum of the mixer truck. This cleanout water will be dumped into a wash water tank located near the batch plant. The wash water tank will be sampled at the end of each shift, and, when found clean, will be pumped into a batch plant cleanout water tank. The contents of the batch plant water cleanout tank will be incorporated into the next grout batches. This saves approximately 100 gal of water per batch delivered.

10.6.2 Grout Injection System Cleanout

A double wiper gland that contains a very soft wax pressurized between the two wipers will be installed so that the drill stem can be coated to prevent formation of potentially contaminated grout dust on the drill stem above the gland. This saves cleaning the drill stem before cleaning the system.

The cleanout truck will be moved near the grout injection system. With the jet bit inserted 3 to 4 ft. in the ground, the trackhoe drill operator will flush the remaining grout into the ground with low-pressure air (see Section 10.1.11). The operator mechanically removes the bit and drops it in the mud. The fixative is sprayed on the drill stem threads. The operator then places the drill in position, the drill stem is extended into the cleanout tank, and a high volume flush is performed for 30 seconds. The drill stem is extracted and a new jet bit attached. The operator will then perform a dynamic hydro test of the drill equipment in accordance with Section 7.2.4.

The dynamic hydro test water and cleanout water tanks would be sampled, and, when found clean, would be pumped into the agitator cleanout tank for reuse in the next grout batches.

10.6.3 Cleanout Water and Unused Grout

The contractor, or subcontractor, contingent upon the terms of the subcontract, will construct a series of lined pits for holding any excess cleanout water and unused grout in an area determined by contractor waste management personnel. When the contents of these pits have dried, they will be hauled to the landfill.

10.7 Project Turnover to Operations

The project will be turned over from the subcontractor to the contractor as specified in project and subcontract documentation. After turnover, ISG Project personnel will continue to oversee overall ISG-related activities, with RWMC operations performing the work activities.

11. GROUTING LESSONS LEARNED

This section contains identified lessons learned that apply to grouting accidents and incidents that have occurred at the INEEL, and more globally, to accidents and incidents involving excavators, backhoes, and other related construction equipment at other DOE sites and in private industry.

A National Institute for Occupational Safety and Health (NIOSH) review of the Bureau of Labor Statistics Census of Fatal Occupational Injuries data identified 346 deaths associated with excavators or backhoe loaders during the 1992 to 2000 timeframe (NIOSH 2002). Review of these data and of NIOSH Fatality Assessment and Control Evaluation cases (NIOSH 2000, 2001) suggests two common causes of injury: (1) being struck by the moving machine, swinging booms, or other machine components; or (2) being struck by quick-disconnect excavator buckets that unexpectedly detach from the excavator stick.

Other leading causes of fatalities are rollovers, electrocutions, and slides into trenches after cave-ins. A review of INEEL-related occurrences indicates the same conclusions as NIOSH. A review of the INEEL lessons learned database found 13 related accidents. A review of the causal factors indicate that the INEEL accidents could be categorized the same as found in the NIOSH study:

Currently identified applicable lessons learned information gleaned from the NIOSH website, INEEL Lessons Learned database, and other sources include:

2002-290, Drilling Rig Accident Zone 11. Subcontractor employees were in the process of removing a drill rig. The crew had removed all but one section of the drill stem and was attempting to break the connection between the drill stem and the drill bit using a hydraulic wrench and a 60-in. pipe wrench. A 1.5-in. metal pin failed and the helper's hand was pinched when the 60-in. pipe wrench lurched forward.

2002-011, Driller Injured in Pinch Point Incident. A worker on a drilling rig was manually aligning an extension rod to a threaded rod cap when the assembly dropped faster than anticipated severely injuring the worker's hand.

2000-011, An Analysis of Injuries Experienced by Subcontracted Drill Rig Workers at the INEEL—Internal Distribution Only. The results of an analysis of a series of injuries suffered by subcontracted drill rig workers were performed to identify any common cause(s). Other than design issues, none were identified.

2002-021, Subcontractor Injured During In Situ Grouting Accident—INEEL High Priority. A subcontract worker was seriously injured when struck near the left eye by part of a failed underrated swivel elbow, which was a component of a high-pressure grout injection system. This resulted in a type B investigation (Idaho).

2002-001, Drill Rig Accident during Vapor Extraction Project—INEEL High Priority. While performing drilling operations, a discharge swivel unexpectedly released from the supporting chains and fell. The swivel glanced off the head of a worker below and knocked him off the platform resulting in a broken wrist.

2001-302, Slope Stability Study Proves to be Good Work Practice. Prior to dry sonic drilling of a muckpile, a slope stability analysis identified a potential stability hazard. A 50-ft setback was recommended and followed. Heavy rains later contributed to a significant failure of the muckpile slope proving the analysis.

2001-184, Drilling Rig Operator Injury at the Fermi National Accelerator. While removing a section of drill stem with a tong (a specialized tool used as a pipe wrench), a weld failed in the mechanism used to apply force on the tong, which resulted in the tong striking the drill rig operator in the head. This resulted in a type A investigation (Fermi).

2000-167, Drill Stem Falls. Slightly worn threads on a drill rod separated causing the rod (pipe) to fall. The connection had been loosened too much by the driller prior to trying to lift the drill rod.

1999-459, Weld Failures on Water Development Drilling Rig. A drill rig operator and a welder identified and reported stressed welds on a rig prior to it being erected. The manager allowed the work to continue without the welds being repaired. The welds broke and the rig fell.

1999-456, Drilling Rig Dust Hog Design Flaw. An air rotary drill rig's solid/air cyclone separator unit (dust hog) failed due to four rivets being eroded by the rock cuttings being blown through it. Two operators were sprayed with rock particles from the rig's main air hose after a joint came apart.

1999-290, Near Miss when Ball and Hook Drop from Drill Rig Boom. Inadequate supervision resulted in a worker raising the wrong line on a drill rig. The ball-and-hook assembly at the end of this line contacted the boom tip and the strain parted the cable. The ball/hook fell damaging the operator's console. This was categorized as a near miss.

1999-335, Underground Utility Struck by Drillers. Inadequate administrative control in the underground utility locating service caused a lack of formality in management structure, support, and oversight. Thus, operating procedures were not in place to prevent striking underground 13.8kV cables.

1997-291, Drilling Accident on Sloped Ground. At INEEL, a drill operator stood on 60° slope while operating a drill, making reaching the controls awkward. He lost his balance, pinching his thumb between the stabilizer and auger. In this situation a platform should be built to support the drill operator.

12. ITEMS FOR CONSIDERATION

This list constitutes the results of research conducted during the conceptual design phase of the ISG Project and during Phase 1, ISG Early Action Project, Be Grouting. For the duration of this project, a separate list of items for consideration will be maintained and updated as new information is obtained. The information will be made available to project contractor and subcontractor personnel as needed for integration into applicable aspects of the project.

1. Contract requirements:

   Contractor and subcontractor responsibilities were not always clearly defined. Bechtel BWXT Idaho, LLC (BBWI) construction forces found themselves holding up the subcontractor as the struggled to address various issues that had not been planned. The contract should clearly define responsibilities, and as a general guideline make the subcontractor be in control of all routine field operations:

   a. Responsibilities for site preparation were not specific causing delays.

   b. Ordering and scheduling delivery of grout delay.

2. Equipment design verification:

   Equipment used for a purpose other than the original design, needs to have the capability of being verified by physical testing under the direction of a qualified engineer per BBWI Management Control Procedures.

3. Grout jets:

   a. Jet orifice work loose:

      The jets showed a tendency to work loose during grouting. The jets should be simple soldered in-place and the bit should be a low-cost item that can be dropped in the mud and left. The optimal design is a system with a pair of jets, 180 degrees apart and at the same elevation, not one above the other. This allows for a lower rpm, which is desirable for increasing penetration.

   b. Wear because of cement type grout:

      The use of cementitious grout will positively result in a faster erosion of the grout jet orifices. Erosion or plugging of the jet orifices is important to note because there must be some method of tracking the erosion or detecting the plugging of the jet orifices. If this is to be done manually, it will require continual close scrutiny, analysis and comparison of the output pressure of the high-pressure grout pump, the grout density, the volume of grout injected for each hole, and the volume of grout returns for each hole. If no effort is made to manually record and analyze the data, the only way to check the erosion of the orifice jets is physical inspection. This will require frequent pauses in the drilling/grout injection process to frisk the drill stem to check for plugging or erosion and decide the course of corrective action.

4. Rupture disk failure:

   The system was designed with a rupture disk set at 8,500 psi. Operating at 8,000 psi several of the rupture disks failed. Suggest using 10,500 psi.

5. Grout containment unit:

   The grout containment unit/thrust block does not allow adjustments to an increase in grout returns. The trackhoe-mounted drill can handle larger volumes of returns without any negative consequences other than having some small amounts of contamination brought near the surface. A polymer spray after approximately 2 hours of grouting minimized this issue. Another mean to remove grout returns from the work area could include a vacuum truck.

6. Void ratio:

   Based on Phase 1 work, void ratios are likely to be much lower than originally projected. No hard data have been received, but a large fraction of the jetted wax grout is returning to the surface because of an absence of void space in the soil being treated. It is speculated that the cause for the increased volumes of grout returns is because of compaction of the overburden soil in years subsequent to flooding of the SDA in high water years. See 7 and 8 below.

7. Soil subsidence:

   A series of soil subsidence have occurred in Rows 50 through 54 in the SDA over the past several years. These occurrences have been 150 to 175 yards from the north end. This indicates that there could be a large void in that area. Some planning needs to be done to ensure that the void is filled.

8. Skill-of-the-craft:

   Skill-of-the-craft is a definition of the inherent skills that each craft discipline is qualified to perform by virtue of their experience and training in the craft discipline. The operators need to have flexibility to make adjustments to operations parameters (e.g., pressure and step time/size) for both the high-pressure pump and the drill rig.

9. Roto-percussion/sonic drill/crane mounted:

   If possible, give the subcontractor the leeway to use different equipment.

13. REFERENCES

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API RP 7G, *Recommended Practice for Drill Stem Design and Operating Limits*

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DOE/ID-10968, *Type B Accident Investigation Board Report, Grout Injection Operator Injury at the Cold Test Pit South*, INEEL, October 15, 2001

DOE Order 5480.20a, *Radioactive Waste Management*

EDF-932, "Waste Characterization Design Basis Accidents"

EDF-4897, "Evaluation and Response to the Grout Accident Investigation Report for the OU 7-13/14 Early Actions Beryllium Encapsulation Project"

EDF-4933, "OU 7-13/14 In Situ Grouting Project Grout Measurement and Control"

EDF-5102, "OU 7-13/14 In Situ Grouting Project Grout Delivery System"

EDF-5122, "OU 7-13/14 In Situ Grouting Project Electrical Utilities"

EDF-5135, "OU 7-13/14 In Situ Grouting Project Grout Storage and Mixing"

EDF-5144, "OU 7-13/14 In Situ Grouting Project Support Facilities"

EDF-5150, "OU 7-13/14 In Situ Grouting Project Support Systems"

EDF-5152, "OU 7-13/14 In Situ Grouting Project Environmental, Safety, and Health"

EDF-5153, "OU 7-13/14 In Situ Grouting Project Hydraulic Excavator and Drill-Injection Rig"

EDF-5162, "OU 7-13/14 In Situ Grouting Project Support Vehicles"

EDF-5146, "OU 7-13/14 In Situ Grouting Project Grout Selection Basis"

EDF-5135, "OU 7-13/14 In Situ Grouting Project Grout Storage and Mixing"

Form 433.35, "Preventive Maintenance (PM) Justification"

INEL/EXT-03-00316, *Feasibility Study Preliminary Documented Safety Analysis for In Situ Grouting in the Subsurface Disposal Area*

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Manual 12, *Training and Qualification*

NIOSH Publication No. 2004-107, Preventing Injuries When Working with Hydraulic Excavators and Backhoe Loaders, http://www.cdc.gov/niosh/docs/wp-solutions/2004-107/default.html, webpage last visited August 25, 2004

PDD-1045, "RWMC Training Program Description"

PDD-1045, "RWMC Training Program"

PLN-127, "RWMC Training Implementation Matrix"

PRD-320, "Pressure System Safety"

STD-101, "Integrated Work Control Process"

TFR-267, "Requirements for the OU 7-13/14 In Situ Grouting Project (Customer, Project, and System)"

Appendix A

Project, Startup, and Operating Documentation

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Appendix A

Project, Startup, and Operating Documentation

The following list of documentation was developed at a stage in the project when it was planned that company personnel would perform ISG operations. The determination of which specific documentation will be developed by the contractor (i.e., the company) or subcontractor will be documented in the project subcontract and other applicable project documentation . Whether developed by the contractor or the subcontractor, it is assumed that some form of the following information will be developed to support project ISG operations:

Project Documentation

- Regulatory authorization
- RWMC safety analysis report amendment
- Project execution plan
- TFRs
- Test and turnover plan
- Training program plan
- Interface agreement
- Radiation monitoring plan
- Grout layout plan
- Well abandonment plan
- Road maintenance and improvement plan.

Startup Documentation

- National Environmental Protection Act (NEPA) documentation
  - NEPA environmental checklist
  - Cultural resources management survey and clearance
  - Threatened and endangered species survey
  - Air permit for discharge into the atmosphere
  - Air emission report
  - Waste minimization and management plan
  - Waste determination disposition forms

  - Solid hazardous waste determination form
  - Transportation plan for waste disposal

- Resource Conservation and Recovery Act documentation
  - Generator treatment plan
  - Effluent monitoring plan

- Waste characterization documentation
  - Waste characterization plan
  - Field sampling plan
  - Sampling and analysis plan

- Safety documentation
  - Health and safety plan
  - As low as reasonably achievable plan
  - Fire safety plan
  - Fire hazard analysis
  - Fall protection plan
  - Hazard plan.

NOTE: *New technical safety requirements (TSRs) will be required to verify the condition of the high-pressure grouting system. Grouting will be performed under the existing RWMC TSR requirements for operating and maintenance procedures.*

Operations Documentation

- Operating procedures and job safety analyses (startup, normal operations, abnormal and emergency operations, maintenance, cleanup, and layup)
- Training materials (startup, normal operations, abnormal and emergency operations, maintenance, cleanup, and layup)
- MSA plan.

Appendix B

In Situ Grouting Waste Water Usage Estimate

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Appendix B

In Situ Grouting Waste Water Usage Estimate

Purpose

This estimate was performed to aid in determining optimum evaporation pond size based on sizes of rinse water supply tanks, excess grout volume that will be wasted when the lines and equipment are rinsed, and waste water volume produced. The ISG Early Action Project is preparing EDF-932, "Waste Characterization Design Basis Accidents," to address waste water management for their project. This EDF can be used (with some modifications) as a basis for the long-term ISG project.

Assumptions

- Mixing plant mixer tank capacity is 370 gal (26 cycles per hour with a Casagrande® mixing plant).
- Mixing plant agitator tank capacity is 1,700 gal (equivalent to 8.5 cycles for almost one ready-mix truck load).
- Distance from batch mixing tank to agitator tank at the SDA fence ready-mix truck loading station is approximately 75 ft.
- The grout-receiving hopper will contain one grout hole volume (157 gal) of excess grout when finishing for the day.
- The hose from the grout pump to the drill stem swivel will be 2-in. inside diameter size.
- The ready-mix trucks will contain approximately 5 gal of grout product after emptying.
- Ready-mix trucks will require 100 gal of rinse water per load for cleaning.
- The cleanout water (after sampling) will be in or pumped into the agitator cleanout water holding tank for reuse in new batches of grout.
- Ready-mix trucks will be used to transport cleanout water tank bottoms and excess unused grout to the evaporation ponds.
- Two evaporation ponds will be used. One will be drying out while the other is being used. The evaporation ponds will be able to absorb and evaporate a 6-in. depth of water per week.

Mixing Plant Cleanout Water Estimate

Flush grout from lines

370-gal mixer tank volume of water to flush through system

Grout product volume = 5 gal (mixer tank and pump) + 10 gal (agitator tank and pump) + 10 gal (3-in. piping at plant) + 78 gal (75 ft of 5-in. line) = 103 gal grout

Rinse mixing plant equipment two times

Use high-pressure sprayer wand and flush equipment twice = 130 gal × 2 times = 260 gal cleanout water.

Subtotal grout product = 103 gal
Subtotal cleanout water = 630 gal

Grout Pump Cleanout and Drill String Cleanout Water Estimate

First, the compressed air line valve connection located immediately downstream of the grout pump, will be opened and 100-psi air will allowed to flow through the system to push the grout into the ground.

Second, the grout receiving hopper and low-pressure pump will be partially filled with water, then the grout product remaining in the hopper bottom and grout pump will be flushed to the flushing manifold by operating the grout pump.

Third, a flush cycle of water will be routed through the hopper, grout pump, and drill stem to the drill stem manifold in the bit change box. This will be followed by a second rinse cycle from the low-pressure hopper pump to the drill stem flush manifold.

The first flush water with the grout product will be routed into a 200-gal minimum size tank on a trailer. The second flush will be routed into a 300-gal tank minimum size on the same trailer. The water in these two tanks will be held until sample results show the water to be clean, then it will be transported to the SDA fence and pumped across the fence into the agitator tank cleanout water tank for reuse in new batches of grout.

Flush grout from grout hopper, grout pump, and line to drill string flush manifold

100-gal grout hopper volume of water

Grout product volume = 157 gal (one grout hole) + 5 gal (grout hopper and low-pressure pump) + 5 gal (grout pump and 2½-in. line, hopper to grout pump) + 26 gal (150 ft of 2-in. high-pressure hose) + 5 gal (drill stem) + 3 gal (drill stem flush manifold) = 201 gal grout

Rinse grouting equipment / lines two times

Use high-pressure sprayer wand and flush hopper and lines to manifold twice = 100 gal × 2 times = 200 gal wastewater.

Subtotal grout product = 201 gal
Subtotal cleanout water = 200 gal

Ready-Mix Truck and Container Cleanout

The ready-mix trucks will be clean at the beginning of the shift. After each load, it is assumed the truck will contain 5 gal of residual grout. The trucks will require cleaning after each load at the mix truck cleanout water tank at the SDA fence. The cleaning water will be in each mix truck holding tank (200 gal).

Clean out ready-mix truck and container

Grout product remaining in trucks – 6 trucks x 5 gal per truck = 30 gal grout
Cleaning trucks – 100 gal × 6 loads per day = 600 gal
Cleaning containers – 3 each x 50 gal. = 150 gal.

Subtotal grout product = 30 gal
Subtotal cleanout water = 750 gal

Total Cleanout Water and Grout Product Estimate per Week

Total grout product (from above) = 334 gal per day × 7 days per week	= 2338 gal/wk
Total cleanout water (from above) = 1580 gal per day × 7 days per week	= 11060 gal/wk
Total grout/water matrix	= 13,398 gal/wk

The following estimate assumes that 10% of the cleanout water in the various tanks remains with the grout bottoms and 90% is reused in new batches of grout.

Total cleanout water reused in new batches of grout = 90% x 11060 gal per week = 9,954 gal per week
Total cleanout water bottoms + grout to be disposed in evaporation ponds =
(10% × 11,060 gal per week = 1,106 gal per week) + (2,338 gal per week) = 3,444 gal per week

Evaporation Pond Size

It is assumed that the lined evaporation ponds will accept 4-in. depth of water grout and waste matrix every two weeks. Use of the ponds will alternate every two weeks, so that one can be drying out while the other is being used.

Pond volume required = (3,444 gal per week) / (7.48 gal per ft^3) = 461 ft^3 per week
Pond area required = (461 ft^3 per week) / (0.33-ft depth per 2 weeks) = 2,794 ft^2

This is an area of about 20 ft × 70 ft for each pond. The ponds need to be spaced to allow access around the entire perimeter with large wheel loaders and dump trucks.

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Appendix C

Training and Operations Information for Conducting In Situ Grouting by Company Personnel

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Appendix C

Training and Operations Information for Conducting In Situ Grouting by Company Personnel

The supplementary information contained in Tables 1, 2, and 3 of this appendix was developed at a stage in the project when it was planned that company personnel would perform grouting operations and equipment maintenance tasks. This work will now be subcontracted. The information is retained here for future use in the event that the contractor (i.e., company) takes over responsibility for grouting operations and equipment maintenance from the selected subcontractor.

Table 1. Clean/Close RWMC Project-specific training plan.

Project Title: In Situ Grouting Project
Project Overview: The In Situ Grouting (ISG) Project conducted at the Subsurface Disposal Area (SDA) is part of the Idaho Completion Project at the INEEL. Waste buried at the SDA presents a potential risk to the Snake River Plain Aquifer from subsurface vapor-phase and aqueous transport of contaminants. For this reason, in situ grouting (injection of liquid concrete into the waste zone) will be performed to stabilize waste materials and minimize the migration of contaminants of concern into the under burden soil. This project will include the injection of grout into the waste zone utilizing a track hoe drill; high-pressure and low-pressure grout pumps, cement mixer, water tanks and other support equipment. Radiological monitoring will occur throughout the execution of drilling and grout pumping activities.
Regulatory Compliance Drivers (Documented Safety Analysis, FFA/CO, etc.) 29 CFR 1910.120 FFA/CO DOE Order 5480.20a
General Training Requirements *(Training shall be accomplished in accordance with PDD-1045, "RWMC Training Program," PLN-127, "RWMC Training Implementation Matrix," and Manual 12, "Training and Qualification")* ▪ Completed job analysis for each operations position ▪ Developed task-to-training matrix ▪ Developed case files for affected positions ▪ Job codes have been updated, and/or created for project positions ▪ Qualification codes have been entered into the TRAIN system ▪ Qualifications have been added to the Qualified Watch Stander List
Job Titles: Trackhoe/drill operator (THO) High-pressure pump operator (HPO) Low-pressure pump operator (LPO) Radiological control technician (RCT) Laborer Foreman Data recorder (DR) Shift supervisor (SS) Technical staff (TS)

Summary of Training Requirements by Position:							
Job:	*Education, Experience*	*Pre-requisite qualifications, courses, or job codes*	*Qualification, Certification, or trained position?*	*Initial training requirements*	*Duration, retraining, and proficiency requirements*	*Approving Manager*	*Medical Surveillance requirements*
THO	HS diploma or equivalent	Heavy Equipment Operator qualification	Qualification	ISG systems school, THO HEO qualification checklist, Comprehensive written exam	2 years. Biennial written exam	Shift Operations Manager	Nuclear facility operator, Hazardous waste worker, Respirator wearer
HPO	HS diploma or equivalent	Equipment Operator qualification	Qualification	ISG systems school, HPO qualification checklist, Comprehensive written exam	2 years. Biennial written exam	Shift Operations Manager	Nuclear facility operator, Hazardous waste worker, Respirator wearer
LPO	HS diploma or equivalent	Equipment Operator qualification	Qualification	ISG systems school, LPO qualification checklist, Comprehensive written exam	2 years. Biennial written exam	Shift Operations Manager	Nuclear facility operator, Hazardous waste worker, Respirator wearer
RCT	HS diploma or equivalent, 1 year job related	INEEL RCT qualification, RWMC RCT qualification	Qualification	ISG systems school, Facility-specific checklist	2 years.	RadCon Manager	Nuclear facility operator, Hazardous waste worker, Respirator wearer
Laborer	HS diploma or equivalent	None	Trained position	ISG systems school, ISG Laborer qualification checklist	No timeframe designated	NA	Nuclear facility operator, Hazardous waste worker, Respirator wearer
ISG Foreman	HS diploma or equivalent, 3 years nuclear facility experience	RWMC Basic Foreman	Qualification	ISG systems school, ISG Foreman qualification checklist, Comprehensive written exam	2 years. Biennial written exam	Nuclear Facility Manager	Nuclear facility operator, Hazardous waste worker
DR	HS diploma or equivalent	None	Trained position	ISG systems school, ISG Data Recorder qualification checklist, Comprehensive written exam	2 years. Biennial written exam	Shift Operations Manager	None
SS	HS diploma or equivalent, 3 years nuclear facility experience	RWMC SS qualification	Qualification	ISG SS qualification checklist, Comprehensive written exam	2 years. Biennial written exam	Nuclear Facility Manager	None
TS	Bachelor of Science, 2 years job-related, 1 year nuclear	RWMC Technical Staff qualification	Qualification	Complete ISG-specific addendum to RWMC TS qualification	One time	Cognizant Manager	None

Table 2. Project operations parameters.

	2005 Operating Plan	2006-2010 Operating Plan
Start Training & Season Start-Up	1st Wk May	1st Wk Mar
Start Field Operations	1st Wk Jul	1st Wk May
Complete Field Operations	Last Wk Oct	Last Wk Oct
Number of Shifts per Day	1	1
Number of Crews per drill rig	1	2
Number of operating Drill Rigs	1	3
Number of Drill Units for spares.	0	1
Shift Length (hrs)	12	12
Days Per Work Week	4	7
Crew Hrs at Facility Work Day	12	12
Operational Hours per Day	12	12
Number of Weeks Per Year	17	25
Total Days Per Year	68	175
Pre-Job/Start Up/Leak Test (hrs)	1.5	1.5
Shift Turnover (hrs)	0.0	0.0
Delays (hrs)	1.5	1.5
End of Shift Clean Out (hrs)	2.5	2.5
Effective Work Hours Per Day	6.5	6.5
Holes per Day	52	156
Grout volume per day (gal)	9,209	27,628
Holes per Week	208	1,092
Injections per Season	3,120	27,300
Length of Trench per Season (ft)	1,001	8,756
Grout volume per year (gal)	552,569	4,834,983
Annual Number of 1,000 Ft Trenches	1.0	8.8

Job Crew Breakdown Information (Number of Staff)

Operations		
Operator - HEO	2.00	4.00
Job Supervisor & SSO	1.00	2.00
Roving FTL (JS Relief)	0.25	0.50
HP / LP Pump Operators	3.00	6.00

Overall Operating Basis:

Injections in Waste	212,405
Perimeter injections around Pits/Trenchs	66,726
Total Number of Injections	279,131

Trench Foundation Grouting (not required)

Length of Trenchs	0
Column Spacing along Trench	10
Columns put every 10'	0
Additional grout into overburden	0
Trench Foundation Injections	0

Trench Encapsulation Grouting

Length of Trenchs	44,374
Column Spacing along Trench (in)	17.3
Columns across trench width	4.5
Additional grout into overburden	0
Injections in Trench	138,348
Extra Row around Trench	62,112
Trench Encapsulation Injections	200,461

Pit Encapsulation Grouting

Area of Pits	188,439
Center Spacing of Columns (in)	20
Area taken by each column (sq ft)	2.8
Additional grout into overburden	0
Encapsulation Injections	67,784
Perimeter Injections	4,614
Pit Encapsulation Injections	72,398

Pit Foundation Grouting

Area of Pits	627,240
Center Spacing of Columns	10

	2005 Operating Plan	2006-2010 Operating Plan
Positioner / Grout Estimator	1.00	2.00
RadCon Tech	2.00	4.00
Facility RCT (Relief)	0.25	0.50
Laborer	1.00	2.00
Total Crew per Drill Rig	10.50	21.00
Total Crew	10.50	63.00
Maintenance		
Mechanic	0.13	0.50
Fitter	0.13	0.50
Instrument Tech	0.25	0.50
Electrician	0.13	0.50
Safety / IH	0.00	0.13
Total Maintenance	0.63	2.13
Other Project Support		
Support per Crew	2.25	7.50
Project Total	**13.4**	**72.6**

Overall Operating Basis:

Columns in Foundation cluster	1
Area taken by each column	100
Additional grout into overburden	1
Pit Foundation Injections	6,272

Additional Assumptions

Grout volume per foot (gal)	13.6
Average height of column (ft)	13
Height to grout into overburden (ft)	1
Grout Volume Foundation Column (gal)	190
Grout Volume Encapsulation Column (gal)	177
Typical length of trench (ft)	1,000
Nominal Grout column diameter (inches)	24
Injections Per Hour	8
Drill to Basalt (min)	2.0
Grouting time per hole (min)	3.5
Ave Reposition time to hole (min)	2.0
Total Time per hole (min)	7.5
Fuel use per hour (60% Full Load) (gal)	52

Table 3. Contaminant and foundation grouting parameters.

Contaminant Grouting				Foundation Grouting			
Trench	***Area (sq ft)***	***Width (typical) (ft)***	***Length (calculated) (ft)***	***Trench***	***Area (sq ft)***	***Width (typical) (ft)***	***Length (calculated) (ft)***
1	0	7	0	1	8043	7	1149
2	0	7	0	2	8015	7	1145
3	0	7	0	3	7777	7	1111
4	0	7	0	4	7812	7	1116
5	0	7	0	5	8155	7	1165
6	0	7	0	6	7826	7	1118
7	0	7	0	7	8120	7	1160
8	0	7	0	8	7826	7	1118
9	0	7	0	9	8610	7	1230
10	0	7	0	10	8092	7	1156
11	6279	7	897	11		7	0
12	12502	7	1786	12		7	0
13	5439	7	777	13		7	0
14	10969	7	1567	14		7	0
15	5495	7	785	15		7	0
16	10801	7	1543	16		7	0
17	4270	7	610	17		7	0
18	7180	7	1026	18		7	0
19	9905	7	1415	19		7	0
20	7000	7	1000	20		7	0
21	2630	7	376	21		7	0
22	2658	7	380	22		7	0
23	3098	7	443	23		7	0
24	2948	7	421	24		7	0
25	7001	7	1000	25		7	0
26	3115	7	445	26		7	0
27	7013	7	1002	27		7	0
28	3097	7	442	28		7	0
29	2423	7	346	29		7	0
30	7014	7	1002	30		7	0
31	3104	7	443	31		7	0
32	2457	7	351	32		7	0
33	7013	7	1002	33		7	0
34	7280	7	1040	34		7	0
35	7012	7	1002	35		7	0

Contaminant Grouting				Foundation Grouting			
Trench	***Area (sq ft)***	***Width (typical) (ft)***	***Length (calculated) (ft)***	***Trench***	***Area (sq ft)***	***Width (typical) (ft)***	***Length (calculated) (ft)***
36	8610	7	1230	36		7	0
37	7003	7	1000	37		7	0
38	6421	7	917	38		7	0
39	6993	7	999	39		7	0
40	7292	7	1042	40		7	0
41	7001	7	1000	41		7	0
42	7952	7	1136	42		7	0
43	6667	7	952	43		7	0
44	3504	7	501	44		7	0
45	7959	7	1137	45		7	0
46	6703	7	958	46		7	0
47	7966	7	1138	47		7	0
48	6685	7	955	48		7	0
49	7728	7	1104	49		7	0
50	6601	7	943	50		7	0
51	7987	7	1141	51		7	0
52	6349	7	907	52		7	0
53	8057	7	1151	53		7	0
54	6373	7	910	54		7	0
55	8134	7	1162	55		7	0
56	8134	7	1162	56		7	0
57	6346	7	907	57		7	0
58	6447	7	921	58		7	0
Totals	**310615**		**44374**		**80276.0**		**11468.0**
Equivalents	**7.1 acres**		**8.4 miles**		**1.8 acres**		**2.2 miles**

Pit	***Area (sq ft)***	***Perimeter (ft)***	***Pit***	***Area (sq ft)***
1.0	0.0		1.0	24913.0
2.0			2.0	78425.0
3.0			3.0	41830.0
4.0			4.0	107082.0
5.0			5.0	108754.0
6.0			6.0	54984.0
7.0	100.0	130.0	7.0	
8.0	31294.0	915.0	8.0	
9.0			9.0	45541.0
10.0			10.0	110942.0

Contaminant Grouting				Foundation Grouting			
Trench	***Area (sq ft)***	***Width (typical) (ft)***	***Length (calculated) (ft)***	***Trench***	***Area (sq ft)***	***Width (typical) (ft)***	***Length (calculated) (ft)***
11.0				11.0	24859.0		
12.0				12.0	29910.0		
13.0	19290.0	890.0		13.0			
14.0	40704.0	1997.0		14.0			
15.0	74805.0	1970.0		15.0			
16.0	22246.0	750.0		16.0			
Totals	**188439**	**6652**			**627240**		
Equivalents	**4.3 acres**				**14.4 acres**		